

# Executive Summary

Deployment of forces in hostile or unfamiliar environments is inherently risky. The changing missions and increasing use of U.S. forces around the globe in operations other than battle call for greater attention to threats of non-battle-related health problems—including infections, pathogen- and vector-borne diseases, exposure to toxicants, and psychological and physical stress—all of which must be avoided or treated differently from battle casualties. The likelihood of exposure to chemical and biological weapons adds to the array of tactical threats against which protection is required. The health consequences of physical and psychological stress, by themselves or through interaction with other threats, are also increasingly recognized. In addition, the military's responsibility in examining potential health and safety risks to its troops is increasing, and the spectrum of health concerns is broadening, from acute illness and injury due to pathogens and accidents to possible influences of low-level chemical exposures, which can manifest themselves in reproductive health and chronic illnesses years later, perhaps even after cessation of military service.

Some well-publicized cases have led to scrutiny of the military's procedures for identifying potential hazards and for collecting the information on hazards, exposure, and health-status surveillance that is necessary to detect and monitor threats to the troops' health and welfare.

To help prevent and reduce the number of illnesses in future deployments, the Department of Defense (DOD) asked the National Academy of Sciences (NAS) to advise it on a long-term strategy for protecting the health of the nation's military personnel when deployed to unfamiliar

environments. In response to this request, a collaborative effort was established between the Institute of Medicine (IOM) and the National Research Council (NRC) and four tasks were identified as key to addressing DOD's request. They were: (1) develop an analytical framework for assessing health risks to deployed forces; (2) review and evaluate technology and methods for detection and tracking of exposures to potentially harmful chemical and biological agents; (3) review and evaluate technology and methods for physical protection and decontamination, particularly of chemical and biological agents; and (4) review and evaluate medical protection, health consequences management and treatment, and medical record keeping.

This report addresses the first task of developing an analytical framework for assessing risks, which would encompass the risks of adverse health effects from battle injuries, including those from chemical- and biological-warfare agents, and the non-battle-related health problems noted above. The presumed spectrum of deployment ranged from peace-keeping to full-scale conflict.

### **APPROACH TO THE CHARGE**

This report was prepared by Dr. Lorenz Rhomberg of Gradient Corporation (formerly of the Harvard School of Public Health), with the help and guidance of 10 advisers who represented various scientific disciplines, including military operations, toxicology, infectious diseases, use of biomarkers, personal exposure assessment, epidemiology, occupational health, psychiatry, and risk assessment (see Appendix B). The group received briefings, reviewed documentation of current DOD practices, considered existing risk-assessment paradigms, and commissioned the preparation of papers on six topics that required in-depth analyses (see Appendix A for abstracts of these papers).

The focus of this report is principally on risk assessment—the identification, characterization, and quantitative description of threats and the impacts they may produce—rather than on the means to control or manage those impacts. It must be borne in mind, however, that such risk assessment must occur within the military context, aimed at enhancing the health and safety of troops while ensuring their military effectiveness, both strategically (through improvement of equipment, doctrine, training, and preparedness) and in actions taken during specific deployments. While the risk assessment framework recommended in this report does not directly address how to put its characterizations of threats to use in risk management decision-making, it does attempt to steer the conduct of risk assessment activities so as to provide the most useful and appropriate information while avoiding critical gaps.

Because of the diversity of threats that the recommended framework must be able to address, it cannot be very specific about any one activity, and it does not try to be a flowchart or decision tree that maps out a process, step by step. The term “framework” as used herein means an organized context for conducting assessment activities that defines the relationship of the component activities to the achievement of the larger aims of protecting the health of deployed forces. Rather than a prescription of a specific program or a plan for its implementation, the framework is a set of strategies for conducting risk assessment activities so as to be most useful to the military’s needs. Accordingly, emphasis is placed on examining how those needs differ from the more widely familiar context of environmental risk assessment. The NRC’s 1983 risk-assessment paradigm forms the core of the framework, providing a structure for analysis and characterization of particular exposures to particular hazards. The framework recommended herein expands the scope of the paradigm, by showing that the structure can address not only toxic chemicals, but also such other threats as risks of microbial infections, mechanical failures, transportation accidents, and tactical threats. The particular technical methods will vary with the nature of the threat under analysis, and the framework includes ways of modifying standard approaches to be applicable to military situations.

The framework must go beyond the NRC paradigm to organize the process of recognizing how the varied activities entailed in deployment of forces might lead to exposures to hazards that need analysis, cataloging these, setting priorities among them for analysis, analyzing them, and integrating the results so as to yield a comprehensive risk-management program that addresses the full array of threats with which troops must deal during deployment.

Threats to deployed forces can be assessed with the tools developed in the civilian risk-assessment context, but it must be recognized that the military context differs. Many hazards are specific to military situations, military exposure factors can differ from those relevant to civilians, and stress and extreme environments can affect toxic responses. A useful management scheme must address all the threats that deployed troops face, so integration is particularly needed. The military mission has primacy, and its needs might dictate that troops bear risks that would not be acceptable in a civilian setting. Extraordinary measures to protect against threats to health and safety can encumber military effectiveness or increase vulnerability, so well-thought-out tradeoffs among military and nonmilitary concerns are necessary. Risk information must be presented in a way that permits rapid decisions to be made in the field by commanders with little pertinent technical expertise.

For many hazards relevant to military deployments, the concern is not

for continuous low-level exposures, but for episodes that occur as a consequence of unplanned and unpredictable events, such as equipment failures, actions by an adversary, and collateral damage of chemical-storage facilities. Risk analysis for such hazards must focus as much on describing the likelihood of toxicologically important exposures as on the responses to exposures. One can analyze such exposures by tracing scenarios leading to exposure of troops and by examining the likelihood that key precipitating events occur, whether they be physical occurrences or actions on the part of adversaries or of the deployed forces themselves. The problem can often be divided into the likelihood that a potential hazard is in the deployment area, the likelihood of release of a hazard into the environment, the likelihood of exposure of troops to the released material (based on fate and transport modeling), and the likelihood of adverse health effects, given the exposure (based on dose-response analysis).

No attempt is made in this report to assess particular individual risks or to critique the current DOD systems or established risk-assessment practices, nor is any attempt made to create a comprehensive catalog of threats. The risks of injury from conventional weapons or nuclear weapons are not addressed herein, and psychological stress is addressed only in general, because of the lack of established ways to assess the risk of such stress. This omission is a shortcoming of the risk assessment framework recommended in this report, since psychological stress is a factor of major importance to the health of deployed forces and deployment veterans, and any solution to how DOD should approach disorders and unexplained symptoms among veterans must include consideration of the contribution of stress. Further work on this topic is recommended.

A risk-assessment framework should be a means to help achieve DOD's program objectives for addressing the health and safety risks to deployed forces, so such objectives must be clearly defined. It is provisionally suggested that they should include minimizing the impact of disease and non-battle-related injuries; developing a straightforward and systematic program to address risks and executing the program efficiently; diligently and competently addressing health and safety threats; integrating risk awareness and the appropriate weighing of risks and benefits into decision-making; improving the ability to characterize risks posed by past exposures; and doing all the foregoing in the light of cost and effects on military capability and effectiveness. The recommended framework attempts to bring the methodology of risk assessment to bear on these objectives.

The process should be open, encouraging scrutiny of DOD actions and the incorporation of health and safety concerns into all aspects of decision-making. Emphasis should be placed on proactive recognition of potential threats, and characterizing and setting priorities for them; moni-

toring for detection and characterization of known threats and their impacts; and ongoing and retrospective surveillance of troops’ (and veterans’) health status for effects that may arise despite protective efforts.

DESCRIPTION OF THE FRAMEWORK

The recommended framework is a structured approach to gathering, organizing, and analyzing information in a way that encourages a comprehensive, integrative assessment and response to the threats that deployed troops might face. Unlike more traditional risk assessments, the recommended framework is concerned with examining *activities* (such as deployment near an industrial facility that stores various toxic chemicals) rather than *specific threats*. Focusing on the threats associated with particular military deployment activities, rather than specific threats, encourages thinking beyond a standard list of recognized hazards, facilitates redesign of practices and materiel to mitigate risks, and avoids increasing one risk to reduce another. By emphasizing planning and attention to previously uncharacterized threats, the framework aims to minimize the likelihood of overlooking important risk factors. Characterizing the effects of various levels of exposure, as opposed to simply defining “safe” levels, increases the ability to make appropriate tradeoffs.

The recommended framework for risk assessment of threats to deployed U.S. forces is composed of three phases, which are characterized by the timeline of deployment: ongoing, deployment, and post-deployment (see Table E-1).

TABLE E-1 Framework for Phases of Risk Assessment

Ongoing Strategic Baseline Preparation
Anticipation of potential threats and circumstances
Priority-setting for detailed analyses
Risk analysis
Incorporation of results into planning
During Deployment
Deployment-specific planning
Initial activities
Continued deployment
Activities to terminate deployment
Post-deployment
Reintegration of troops
Data archiving
Continuing health surveillance
Population analyses of exposure effects
Evaluation of lessons learned

### Ongoing Strategic Preparation

The ongoing strategic baseline preparation phase of the framework involves all the activities and analyses undertaken to prepare for threats in future deployments. The activities are not tied to particular deployments, but represent the need for continuing development of information about potential deployment risks and exposures, organized through the framework so as to create an ever expanding and improving base of knowledge. This knowledge can be drawn upon to increase the capability to avoid or mitigate risk and to refine doctrine and training so as to lead to safer deployments.

Ongoing preparation has four steps: anticipating potential threats and the circumstances under which they might arise, setting priorities among the potential threats for analysis, conducting qualitative and quantitative risk analyses of the threats, and incorporating the resulting risk estimates into exposure guidelines and planning. In the first step, established lists of hazardous threats (such as toxic chemicals, infectious disease agents, insecticides, and vaccines) are reviewed, and threats with notable exposure patterns are examined. Potential threats can be identified by constructing deployment scenarios and placing hazards in three categories: those associated with deployment-specific activities (such as heat stress), those associated with particular types of missions (such as peace-keeping and ground combat), and those associated with particular locations (such as climate, indigenous diseases, and local pollution). In addition to identifying potential exposures to threats, the scenario-drawing process helps to link exposures directly to the activities that cause them and to delineate chains of events that lead to particular outcomes. It is important to consider in this step the potential for coexposures (such as vaccinations, antidotes, and pesticides) that could lead to accumulative or synergistic effects.

Once the potential threats to deployed troops are identified, priorities must be set for analysis. That is done by examining the most likely deployment scenarios and determining which hazards are most likely, which are mission-critical (would affect the chance of success of the military mission), which constitute known threats, which could have widespread or severe effects, and which are peculiar to the deployment setting—all features that suggest priority attention.

Once the hazards and the circumstances under which they might arise are identified and ranked, the traditional tools of risk assessment can be used to develop quantitative or qualitative risk estimates. In the dose-response analysis, consideration should be given to potential interactions with other threats, the duration of exposure, and the importance of dose-rate effects. For each potential hazard, it is also important to

examine the possible scenarios that lead to an adverse outcome and to recognize that some scenarios require a chain of events to produce the outcome, in which case the probability of each scenario is based on the probabilities of the separate events.

An important step in the ongoing strategic baseline preparation phase of the framework is the incorporation of the risk-assessment results into planning, design of doctrine and standard operating procedures, and training. For example, exposure standards can be established for achieving some degree of protection under different circumstances (such as short-term emergency exposures and chronic low-level exposures). Because detailed risk analysis can be time-consuming, appropriate generic analyses and contingency plans that can quickly be adapted to and implemented in actual deployment situations should be formulated. Such formulations should take account of the fact that different deployment missions will have different spectra of tactical risk, as well as different opportunities and costs for health protective measures.

### **During Deployment**

The second major phase of the framework addresses risk-assessment activities associated with actual specific deployments, either as case-specific pre-deployment planning preparation or as activities conducted during the course of deployment. The key activities associated with this phase are implementing plans made in anticipation of deployment (ongoing strategic baseline preparation and planning), refining them with information peculiar to the specific deployment, noting the advent of threatening exposures, and activating the appropriate parts of the response plans accordingly. This phase must also include vigilance for exposures that, despite all the planning, were unanticipated. DOD should examine the effectiveness of collecting and archiving biological samples, in addition to sera, from troops and environmental samples for future analysis. Such information could provide rapid results during deployment so that risk management can be continually refined. This information could also validate and refine baseline strategies.

When a specific deployment is expected, information on its location, mission, and current conditions should be incorporated into predesigned generalized contingency plans. This includes information on meteorological conditions and forecasts, updates on the locations of hazardous materials, and current assessments of capabilities and inclinations of adversaries. A plan to obtain information on potential exposures during the course of deployment should be specified; its extent will depend on the nature, magnitude, and anticipated duration of the specific deployment. On arrival at a deployment destination, samples of soil, air, and water

should be obtained and tested for local pollutants, and some samples should be archived for future reference. In addition, detection devices for the most likely threats and meteorological instruments should be set up to obtain information for use in exposure models.

Over the course of the deployment, various kinds of information should be collected periodically (with the extent of the activity depending on the deployment specifics): environmental samples to document changes in environmental concentrations, information on unit activities and positions, and information collected by monitors and detectors. DOD should examine the effectiveness and feasibility of collecting biological samples during deployment. It is also important during the course of deployment to be vigilant for novel and unanticipated threats.

The information collected during deployment is valuable for retrospective analyses, such as reconstruction of exposure scenarios, comparisons with pre-deployment health surveys and samples, and improvement in contingency plans. These data constitute an important source of information for investigating health issues that might arise among deployment veterans.

### **After Deployment**

Post-deployment risk assessment is the third major phase of the framework. In this phase, the health of deployment veterans is monitored for later-appearing effects, and analyses are conducted to ascertain whether these effects are associated with exposures experienced during deployment.

DOD should consider the effectiveness of collecting and archiving health information and biological samples after deployment for the purpose of follow-up and retrospective analyses to address questions about illnesses that might arise later. Surveillance of veterans' health should be continued, and uncertain outcomes should be investigated with exposure reconstruction and epidemiologic analyses. Much of the information obtained about threats during this phase of the framework can be used to refine the ongoing strategic baseline risk analyses by providing a deeper understanding of known threats and by identifying threats not previously considered.

## **RECOMMENDATIONS**

The risk-assessment framework presented in this report should be used by DOD as a basis for organizing its efforts and learning what kinds of work are needed for the protection of the safety and health of forces deployed in hostile environments.



What will make the framework most useful is not the execution of each of its elements, however competently done, but rather the systematic approach to the process of assessing threats to deployed troops and incorporating the results of each element of analysis into an integrated program that addresses the overall objectives of the troop health-protection program.

In implementing the framework, DOD should

- Develop an explicit list of objectives, such as those described in this report, for efforts to protect the health and safety of deployed forces and to periodically assess progress in meeting the objectives.
- Strive to examine and reexamine as warranted all the effects of a given hazardous agent or threat, not only the effects that were first known, including risks posed by low exposures that could eventually lead to chronic illness.
- Continue to conduct research on methods to address different magnitudes, durations, patterns, and coexposures that might be encountered during deployment.
- Develop risk-assessment methods to characterize and predict effects of psychological and physical stress in potentiating or exacerbating the physical, chemical, and biological effects of hazardous agents or threats and as hazards in their own right.
- Conduct research and develop methods to assess risks posed by exposure to microbial agents, and strive to characterize the variety of disease organisms that might be encountered around the world and troops' vulnerability to them.
- Examine patterns of coexposure to various threats; because deployment is characterized by many simultaneous exposures, develop methods to assess possible effects of combinations of threats and their interactions with stress; and develop methods to identify the combinations that should receive further scrutiny based upon biological considerations, because they are peculiar to specific kinds of deployment, or because of particular DOD responsibilities.
- Make special efforts to identify previously unrecognized hazards by examining deployment activities and settings for potential threats and by identifying scenarios that might lead to hazardous exposures.
- As an aid to decision-making in emergencies related to particular hazardous substances, compile and make readily accessible the exposure levels and durations at which people are expected to begin to suffer progressively severe effects.
- Conduct expert analyses before deployment to update general scenarios with case-specific details for quick application by field commanders.

- Conduct research on developing appropriate biological markers of exposure and effect for surveillance of exposures that are of particular relevance to the deployment setting.
- As part of the tracking of troops' exposures and activities, DOD should consider the effectiveness of collecting and archiving biological samples, in addition to sera, from troops and environmental samples before, during (if warranted and feasible), and after deployment.
- Conduct annual health evaluations of reserve and active-duty personnel to obtain baseline health information, as recommended in the companion IOM report addressing medical surveillance.
- Develop an explicit framework for risk-management decision-making that would use information obtained from the application of the risk-assessment framework.